STANDARDIZED PROCEDURE FOR EXPRESSING ODOR INTENSITY

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We wish to propose a standardized way to express the perceived intensity of odors. There are currently in use various procedures for the assessment of odor magnitude. These techniques include (a) equal intensity matches (where various levels of one odorant are matched in perceived magnitude to another odorant), (b) threshold measures (where odor intensity is expressed in terms of multiples of threshold concentration), (c) one or another type of category (interval) scaling procedure, and (d) ratio scaling procedures. Each technique yields its own scale of measurements. Often, the information obtained in one experiment would be useful to other investigators, but the lack of a standardized scale and unit for odor intensity measurement precludes the exchange of useful measurements. In many instances it is impossible for the reader of a report to decide whether an experimenter used stimuli of high, medium, or low intensity. The need for a standardized scale is particularly necessary in olfaction, where the potential stimuli (odorants) number in the thousands and where the stimulating effectiveness of one odorant may be very different from that of another.

We propose that workers in olfaction use a reference scale that is based on techniques of sensory measurement collectively known as 'ratio scaling' methods. We have noted that when l-butanol vapor is diluted in air, and its various concentrations are presented to subjects by dynamic, flowing procedures, a relatively simple power function, $S=kC^n$, where $n\approx0.66$, related judged odor magnitude (S) to concentration (C) (Cain, 1969; Dravnieks and Laffort, 1972; Laffort and Dravnieks, 1973; Moskowitz *et al.*, 1974). The psychophysical method used to obtain the judgments was magnitude estimation: subjects assigned numbers proportional to odor magnitude. A stimulus consisting of 250 ppm by volume of l-butanol in air appears to be subjectively neutral to an average observer, possessing a balance of pleasant and unpleasant characteristics. It is perceived as neither too strong nor too weak. We propose that the odor intensity of this stimulus be designated arbitrarily as '10' odor intensity units. Then $k= =10/250^{0.66}$. The butanol function is $S=0.261\ C^{0.66}$ or $\log S=0.66\log C-0.583$, where C is the concentration of l-butanol in ppm by volume, in air. Other butanol

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concentrations can be assigned odor intensity values in accordance with the power function for butanol. Since the odor threshold of 1-butanol is in the range of 2 to 5 ppm, the proposed equation will give odor intensity values on the order of 0.5 in the vicinity of threshold, denoting difficult-to-detect intensities. The resulting scale will possess the properties of a ratio scale. Figure 1 shows the proposed butanol scale, plotted in log-log coordinates.

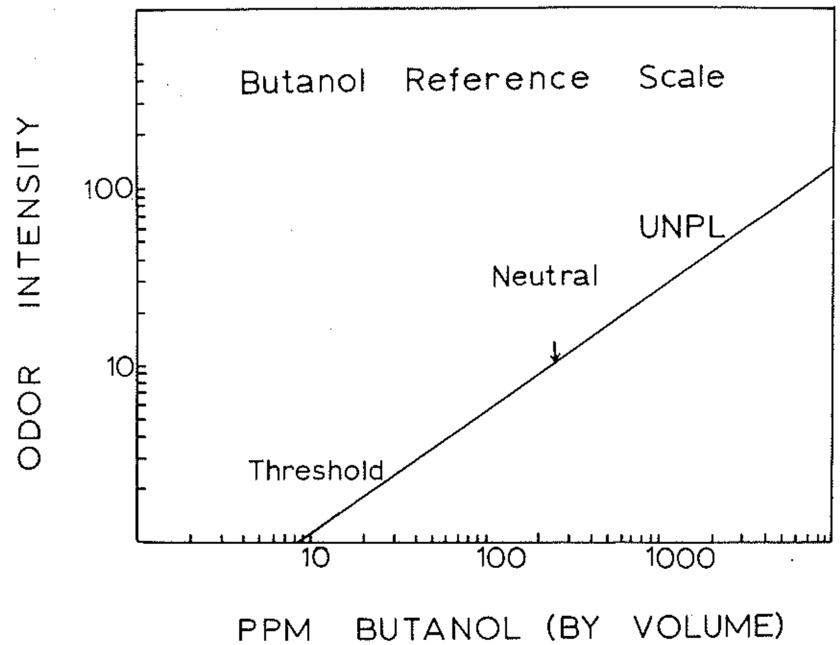

Fig. 1. The butanol reference scale, plotted in log-log coordinates. The equation of the line is: $S = 0.261\,(C)^{0.66}$ (or $\log S = 0.66(\log C) - 0.583$). The regions pertaining to threshold (2–5 ppm), neutrality (about 250 ppm), and unpleasantness (above 250 ppm) are shown. Odor intensity corresponding to a specific concentration (ppm by volume) of butanol is obtained directly by reading the ordinate value corresponding to the butanol level.

In proposing this subjective ratio scale, we note that a similar function, a power function with an exponent of 0.6, has been adopted by the International Organization for Standardization (1966) as the means to concert sound pressure into loudness (in sones) (see Stevens, 1972). The primary psychophysical method used to establish the loudness function was magnitude estimation. There is abundant evidence to show that a power function relates perceived magnitude to stimulus magnitude on most sensory continua (Stevens, 1960). The rate of growth of the function varies from one continuum to another and with certain conditions of stimulation (e.g., the subject's state of adaptation). In olfaction, rate of growth varies from one odorant to another (Cain, 1969; Dravnieks and Laffort, 1972).

We believe that adoption of a standardized system for expressing odor intensity would provide the following substantial benefits to workers in the chemical senses:

(1) In those cases where it is desirable and feasible to match odorants for perceived magnitude, l-butanol could serve as the standard odor reference for the matches, thereby making the results of various laboratories immediately comparable. At present, comparability can be attained by a circuitous route at best. If the proposed scheme is adopted, results of intensity matches, hitherto expressed only in units of concentration, would be expressed in terms of subjective odor intensity as well.

(2) Standardization would yield the opportunity for odor control regulations to be expressed in terms of *perceived magnitude*. Presently, multiples of threshold are used to express the intensity of odor pollutants (Turk, 1973), even though multiples of threshold do not presume to reflect ratios of sensory magnitudes. Since the rate of growth of odor intensity with concentration varies from odorant to odorant, two substances matched in terms of multiples of threshold may produce very different odor intensities.

(3) Communication among the workers of various disciplines would be enhanced, and a step would be taken to provide benchmark stimuli that might be inserted into experiments. These benchmarks would allow comparisons of response magnitude of various detectors, ranging from the olfactory organs of simple invertebrates and insects to the olfactory organ of the human being, and even to artificial noses.

In principle, implementation of the present proposal for a standardized butanol scale would require only that an experiment sample 4 to 6 levels of butanol by the same procedure that it samples and quantifies other odorants used. Results from experiments can be reported both in the units that pertain to an experimenter's particular needs and in the odor intensity units given by the butanol power function.

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